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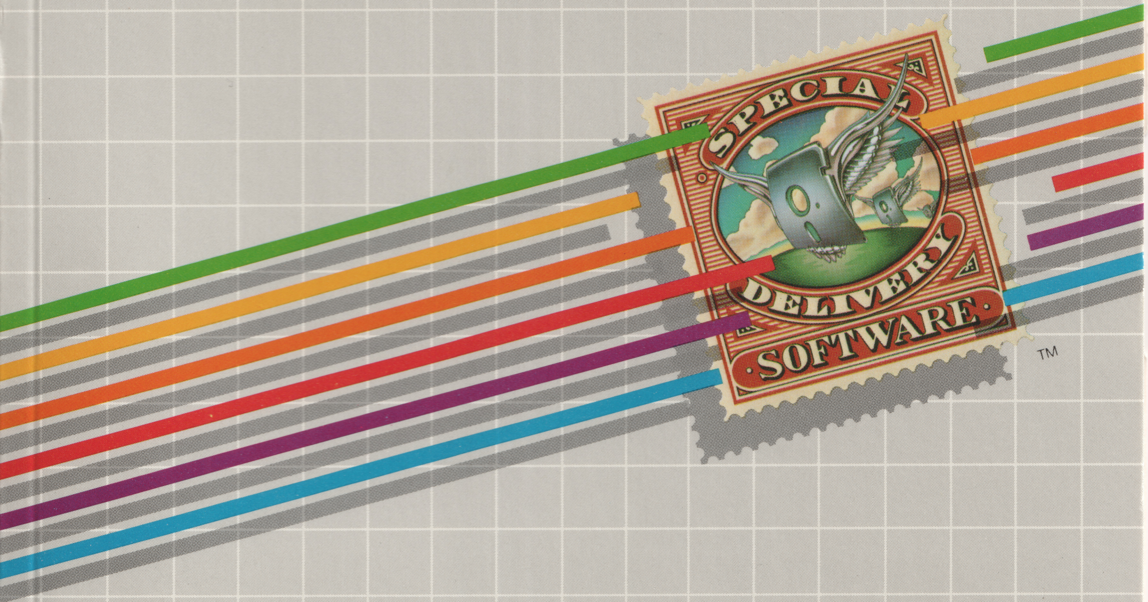

STEPWISE MULTIPLE REGRESSION

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Table of Contents

Introduction..1

Overview..3

Menu..3

Preparing the Required Diskettes................................4

Configuring the Peripherals.....................................4

Create a Set of Variable Diskettes..............................4

Entering Data...5

Data Checking and Adding Variables..............................7

Description of Stepwise Programs................................7

Variable Limitations...11

Appendix A: Computational Time................................12

Appendix B: Setting Up the Apple II System....................13

References...15

Introduction

Linear regression is a method of describing the relationship between variables. If changes in one variable are associated with changes in another, then this function can be approximated by a linear or proportional model. A given set of data determines the form of the linear model, and when a linear equation is described, it can be used to estimate a value of one of the variables given the other. When more than two variables are involved, the analysis is called multiple linear regression or multiple regression. Usually one of the variables is designated as the dependent variable and the others are called independent variables. Other terms commonly used for the independent variables are predictors, or input variables, and for the dependent variable, predicted or output variable.

Although the statistical tests of the model require that the dependent variable have a "normal" or bell-shaped distribution, this restriction is not necessary for the independent variables. That is one of the reasons why the method has been found to be useful in a wide range of applications, since independent variables which are on a dichotomous dimension, for example a yes-no variable, can be used along with variables which are continuous, like age or time.

Stepwise Multiple Regression can be employed when it is considered desirable to select a subset of the independent variables to produce a final regression equation. It is a method for identifying which independent variables provide a "good fit" to the data, in regressing or predicting the dependent variable.

The three most common stepwise methods are:

(1) Forward Stepping - which allows the entry of an independent variable if it adds the most to improving prediction of the dependent variable, and results in a computed F value above a predetermined "F to enter" value;

(2) Backward Stepping - which allows all independent variables to enter initially, but removes a variable if it adds the least to prediction and results in a computed F value which is below a predetermined "F to remove" value;

(3) Hybrid Stepping - which involves a combination of the two above methods. The most common method, and the one used here, is where the following rules apply:

A. If there are one or more variables, which when removed produce a lower F value for the remaining variables, and the reaction is less than that which is below the "F to remove" value, they are removed, stepping one variable at a time since they add too little to the model.

B. If there is a variable, which when added produces a larger F value and the increase is more than the "F to enter" value, the variable is added.

The addition or removal of a single variable constitutes a step. If no additional variables can be removed by rule A, rule B is enacted. If rule B is enacted and a variable is added, then rule A is repeated. If B is enacted and no variable is added, then the stepping is complete.

This manual assumes that your Apple II system is correctly set up. If you're not sure that the system is ready to go, see Appendix B.

Overview

The Stepwise Multiple Regression package is a complete data analysis system. It contains eleven programs. Four of the programs are used in the storage and updating of data maintained on diskettes. Four programs are used to calculate and display the results, and three additional programs support and integrate the system.

All of the programs are "menu" selected from a master diskette and are linked in such a way to minimize the effort in running the system. It runs in Applesoft Basic and requires 48K of core memory. It is only necessary to have one disk drive. A printer, with either a serial or parallel interface, is preferable though not essential to obtain the most useful results. The step output includes: multiple correlation coefficient, standard error, regression coefficients, and F ratio. Also included are the residuals, means, standard deviations, and correlations. Up to 100 variables can be stored and up to 61 variables can be analyzed, and there is no limit to the number of observations.

Menu

Everything that can be done with the Stepwise Multiple Regression system is listed in a menu which has eight choices. It appears on the monitor screen as:

```
STEPWISE MULTIPLE REGRESSION SYSTEM
1.    SYSTEM CONFIGURATION.
2.    CREATE A NEW SET OF VARIABLE
      DISKETTES.
3.    PREPARE A NEW DISKETTE TO BE ADDED
      TO AN EXISTING SET OF VARIABLE
      DISKETTES.
4.    CHECK OR UPDATE OBSERVATIONS.
5.    ADD OBSERVATIONS TO AN EXISTING
      SET OF VARIABLE DISKETTES.
6.    RUN A STEPWISE MULTIPLE REGRESSION
      ANALYSIS.
7.    REDO A STEPWISE MULTIPLE
      REGRESSION ANALYSIS (THE
      OLD COMPLETE CORRECTED
      CROSSPRODUCTS FILE IS USED).
8.    QUIT SYSTEM.
```

The system will always automatically return to the menu when a choice has been completed. To select one of the items it is only necessary to key the number and press RETURN. For example, if after you have set up properly you want to run a Stepwise Multiple Regression analysis, key "6." When the analysis is complete, the menu will appear again.

In the following sections, references will be made to various choices on the menu. In the above example, run Stepwise Multiple Regression would be referred to as menu selection #6.

Preparing The Required Diskettes

Some preparation is required to set up the variable diskettes to receive data. First, determine the number of variable diskettes that you will need. Each variable diskette will hold a maximum of 64 observations, for up to 100 variables, including the dependent variable. If you want to use the sample test data listed in the section "Entering Data", you will only need one variable diskette because there are 15 observations.

Initialize each diskette that you will need. In the sample, after you have initialized the one required diskette, label it "variable diskette #1 - test sample." If there were a large number of observations, several diskettes would be required and they should be numbered consecutively.

Configuring The Peripherals

If you have all the required diskettes initialized, you are ready to start the system.

To begin, boot the system with the master diskette. If you have already booted it with another diskette, re-boot with the master diskette. This will present a question on the screen, "IS THIS THE FIRST TIME YOU HAVE USED THE SYSTEM Y/N?" If it is, then you will have to go through a process of describing the configuration of peripherals that you have and how they are connected to the computer.

Once you've entered the information about your disk drive system, you will be asked to indicate whether you have a printer and with what type of interface. When you have confirmed that all the displayed information is correct, then it will be stored on the master diskette. Following the instructions, you will be returned to the list of menu selections.

Create A Set Of Variable Diskettes

To complete the preparation of the variable diskettes, make menu selection #2. You will be prompted to put variable diskette #1 in the drive and press RETURN when you are ready. If (as in the test sample) there is only one variable diskette, you will then be returned to the menu. If there are multiple variable diskettes, you will have to place each in the drive and wait until you are prompted for the next.

When this program has ended, you will always be placed back with the menu, and will be ready to run the program to enter data.

Entering Data

The following sample test data is provided so that you can enter it and run a complete test with it:

Sample Test Data

Observation #	Var. #1	Var. #2	Var. #3	Var.(Dep.) #4
1.	32	48	54	15
2.	36	33	19	16
3.	3	28	30	14
4.	12	33	64	22
5.	36	34	60	24
6.	24	36	53	19
7.	19	42	29	13
8.	20	33	55	15
9.	27	36	62	23
10.	15	22	33	12
11.	45	46	68	25
12.	9	28	42	17
13.	11	32	45	18
14.	33	34	39	19
15.	21	45	39	18

To start adding data to the variable diskettes, with the master diskette in the drive, make menu selection #5. You will be instructed to put variable diskette #1 in the drive. After you have completed the entry of the number of variables, you will be asked to assign an ID# and name to each of the variables. In the test sample there are four variables and you may wish to give variable #1 the ID# "1", although it could be any other number from 1 to 100. Likewise, give ID#'s for the rest, but make sure that you do not use duplicate ID#'s since that will abort the program. Any name may be used with up to 15 characters in length. The ID#'s allow you to determine what variables you want to be considered in the analysis.

For example, in the sample there are four variables, but you may decide that you want to consider only the first, the third and the fourth. Since you have assigned an ID# to all of the variables, you can specify how many variables and what ID#'s you want in each analysis. Then the screen will show "PUT IN VARIABLE DISKETTE WHICH WILL CONTAIN THE NEW OBSERVATIONS." This instruction may not be clear at first, but there is a reason why it is stated that way. You might conclude that since, in the sample you are just beginning to add data, there is no reason why you should have to switch diskettes. And that is correct. In that case, the diskette that you want to add data to is already in the drive so you can press RETURN.

However, this program is also used to add data to a pre-existing set of data, and in that case you need to find the diskette that is only partially full and put it in the drive to add to it. In either case, after RETURN the screen will display "ENTER THE VALUE OF OBSERVATION #1 FOR -- --- --", where the blank will be the name you gave to variable #1. The remaining variables for the observation should be entered as you are prompted.

In the sample for observation #1, the first variable entry is 32. Moving across, enter each variable for the observation, that is, next enter 48, then 54. You must enter the dependent variable last (in this case variable #4), which for observation #1 is 15. There is about a ten second delay from the entry of the dependent variable until you are given the choice to continue or not. This delay is the same whether you are entering two variables or 100. After each set of observations you will be asked if you want to stop. In the sample, you will reach observation #15 for each of four variable names and then enter "N" which ends the program and returns you to the menu.

The listing of the observation number is only an aid to you to keep track of the data you are entering. If, as in this example, you are adding data to an empty diskette, then the observation number shown is the current number of observations. If you are adding data to a variable diskette that already has several observations on it, don't worry that the observation # begins with "1" when you may be adding the 29th observation to the diskette. The total number of observations are kept track of internally in the program. You just need to be aware that the #1 observation corresponds to the 29th observation on the diskette and #2 is the 30th, etc.

It is important that each diskette be filled with 64 observations before another one is begun, that is, only one partially filled diskette is allowed for a given set of data. If you are ever in doubt whether the variable diskette is full, try to add to it, and if the program ends and returns back to menu, then it was full. If that happens, it is necessary to rerun the program with an empty diskette.

Data Checking And Adding Variables

Menu selection #5 will add observations to a diskette. However, sometimes it's necessary to add new variables to each observation or check the current ones and make corrections to them. To do this, you will need to select menu #4. If you run this program, you will be asked to put variable diskette #1 in the drive. Then you are to enter the number of variables per observation that you want to look at.

Next, you must enter the ID#'s for each variable, and finally, you enter the # of the first and last observation that you are interested in. The program will list variable #1 and the name associated with it. Under that will be the current value, and then the prompt to enter "Y" if you wish to change it or press RETURN to continue. Each set of variables for an observation will be listed, and you will have the opportunity to change it if you want. You can check your entry of the sample data this way, and correct any errors.

If you have more than one variable diskette and you supply numbers which encompass more than one diskette, the program will change them to look at the first diskette only. If you need to look at a second diskette, run the program a second time. Remember that this program cannot add observations to a diskette, but can only add new variables to existing observations, or change those which are already on file.

Description Of Stepwise Programs

Before running the stepwise regression analysis, it is helpful to understand what the four computational programs do. Each of the following programs is linked so that when one program ends, the next one is run:

(1) STEPWISE MULT REGR #1 reads the data off the variable diskettes and computes the sum of crossproducts for all combinations of two variables. It also calculates the sum of each variable and keeps track of the total number of observations. When a correction factor is subtracted from the sum of crossproducts, these values become the corrected crossproducts and are stored on the master diskette with the sums, the number of variables, the number of observations, and the ID# and name of each variable.

(2) STEPWISE MULT REGR #2 uses the intermediate data computed by the first program to determine which variables are selected. This process involves matrix inversion, and matrix multiplication, and many computations of F values which are compared with the "F

to enter" and the "F to remove" values. This program also stores the regression or beta coefficients and constant on the master diskette.

(3) STEPWISE MULT REGR #3 outputs only with a printer. It computes the means, standard deviations, and correlations.

(4) STEPWISE MULT REGR #4 will output the value of the dependent variable for each observation along with the predicted estimate and the residuals which is the difference between the two. This information is only available with a printer, but a graph of the absolute residuals is displayed on the monitor with or without a printer.

To run a complete analysis, select #6 from the menu. After you've entered the number of variables, you will be instructed to put variable diskette #1 in the drive. Enter the ID#'s for each variable, and then the names of the independent or predictor variables will be listed as well as the name of the dependent variable. You will be asked to enter the number of variable diskettes that contain all of the data to be analyzed. For the test sample, enter "1" for the number of variable diskettes.

The monitor will now indicate that computations are being made. For a multiple variable diskette problem (after the computations for the first diskette are completed), you will be prompted to put in the next variable diskette. In the test sample, all of the data is contained on one diskette, so when the program has finished, you will be asked to place the master diskette in the drive. At this point, Stepwise Mult Regr #2 is run automatically, and you need to enter the "F to remove" and "F to enter" values, with the restriction that the F to enter is greater than or equal to F to remove. These F values can be selected for various kinds of stepping:

(1) Forward stepping can be accomplished by setting the F to enter as usual, and the F to remove set equal to zero.

(2) Backward stepping requires setting both F to enter and F to remove equal to zero. After the preliminary computations are complete, the question will appear, "DO YOU WANT TO RESET F TO REMOVE FOR BACKWARD STEPPING Y/N?." If "Y" is answered, an F to remove value is entered and a complete backward stepping is performed. Because of a special restriction, the F to enter value can be ignored since only the F to remove controls backward stepping.

(3) Hybrid stepping is achieved by setting F to enter and F to remove as usual.

For the test sample, enter both F values equal to "2.5." This is an example of hybrid stepping.

If you have a printer the screen will not show any output, and the printer will print in a 80 character per line format. If not, the programs will direct output to the monitor. Before the stepwise computations are begun, a final question is asked concerning your interest in seeing intermediate steps. An affirmative will lead to output whenever an independent variable is added or removed. If you don't want intermediate steps, output related only to the final regression equation is shown.

Assuming (in the test sample) that you do not have a printer and do not want intermediate steps, then the following table will be displayed:

```
NUMBER OF CASES............... 15
TOTAL # OF VARIABLES.......... 4
F TO ENTER.................... 2.5
F TO REMOVE................... 2.5

# OF PRED. VAR. ENTERED....... 2
MULTIPLE R SQUARED............ .806270725
STD. ERROR OF EST............. 2.57849236

ANALYSIS OF VARIANCE
REGRESSION
  DEGREES OF FREEDOM 1........ 2
  SUM OF SQUARES.............. 148.216526
  MEAN SQUARE................. 74.1082628

RESIDUAL
  DEGREES OF FREEDOM 2........ 12
  SUM OF SQUARES.............. 79.7834744
  MEAN SQUARE................. 6.64862287
  F RATIO..................... 11.146408
```

With a RETURN the next screen is:

```
               V#            ID#             VARIABLE        NAME
COEFFICIENT
               3    3                     .182038106
               1    1                     .102744058
                                 CONSTANT 7.25256125
```

Whatever name you have chosen for the variable with ID#3 would appear directly across from the "3" in the table, and likewise for variable ID#1.

If you do not get these values, then either some error in entry has been made, or the program is not functioning properly.

With a printer, the format is slightly different, but comparable. If you had requested intermediate steps, the same table is shown, but the values are determined by how many and which variables appear at each step.

Without a printer, you will be asked if you want a summary table, and if you do, the screen will output:

```
# OF  VAR. VARIABLE NAME    MULT R SQUARED
PRED  ID#
1     3                     .567045381
2     1                     .650072481
```

Here, the first column is the number of predictors, or independent variables. The second column is the ID#, and the name follows with the squared multiple correlation coefficient after that.

From these tables, it can be concluded that the variable with ID#3, which in this case happens to be variable #3, was selected first, and then ID#1 variable, which is variable #1, entered into the regression equation. Variable #2 did not reach the criterion for entry, based on the F to enter and remove.

Then you are asked to put the first variable diskette in the drive. In the sample you will be given instructions, after the first variable diskette, on how to display the graph of the absolute residuals. Since the residuals are defined as the difference between the estimated or predicted value of the dependent variable and the actual value, then the absolute residuals give you a picture of how closely the regression equation fits the data. If all the absolute residuals were zero, then the prediction would be perfect and the graph would be a straight line at the very bottom. It is important to interpret this graph with two things in mind. One is the value of the vertical units of the graph, which can be changed. The other is that residual units are meaningful only in relation to the variability of the dependent variable.

An important characteristic of the graph is that, when the number of observations is greater than 125, averaging of data points is necessary to fit the information on the screen. When that happens, the average absolute residuals are graphed. Two points are averaged when the number of observations are between 126 and 250; three points are averaged from 251 to 375 etc., and since each plotted point in these cases represent more than one observation, it is useful to view the graph of either the maximum or the minimum absolute residuals. In this way, extreme values of absolute residuals can be quickly identified.

If a printer is used, all of the numerical values for the dependent variable, predicted estimate, and residuals are printed out for each observation. In addition, a printer will provide for all the intercorrelations, means, and standard deviations.

Eventually you will be returned to the menu, and if you'd like to redo the analysis answering some of the options differently, it is not necessary to start from scratch. Instead, make selection #7. If you have the master diskette in the drive, the corrected crossproducts and other intermediate computations which have now been stored in files there can be used to complete the analysis. A considerable amount of time is saved by starting with this selection, versus using #6.

Variable Limitations

Up to 100 variables can be stored on the variable diskettes, with 64 observations on each. A stepwise regression analysis can be done with no more than 61 variables, including the dependent variable.

There is no limit to the number of observations or cases.

Appendix A

Computational Time

An approximate formula for the number of computations (additions, subtractions, multiplications, and divisions) is given by Jenrich (1977):

Number Of Computations = m*(m+6)*n + (3/2)*m*m*(m+1) + 2*m*n

Where m equals the number of variables and n equals the total number of cases. Running time is nearly proportional to the number of computations, and an estimate can be calculated from:

Minutes Of Computation = .0004 * (Number Of Computations)

Appendix B

Setting Up The Apple II System

This appendix includes a list of the equipment you'll need to use the programs on your Apple II. You do not need to read all the manuals, but they should be on hand to answer questions that may arise in operating the equipment (e.g., how to boot a diskette).

In order to be able to provide Special Delivery Software at a lower cost, the disks have been copy protected. This software requires an Autostart ROM, and that the Autostart ROM is the only monitor ROM in the system.

To use the Stepwise Multiple Regression program, you'll need the following equipment:

- an Apple II Plus with 48K bytes RAM; or
- an Apple II with 48K bytes RAM and an Applesoft BASIC Firmware Card; or
- an Apple II with the Apple Language System.

PLUS:

- a Video Monitor or Television;
- an Apple Disk II with Controller (16-Sector PROMs);
- a Printer (Optional).

For reference, you should have on hand a copy of the following manuals:

- This Manual (A User's Guide to the Programs);
- Apple II BASIC Programming Manual (Setting up the Apple II);
- DOS Manual (How to Boot the Diskettes).

Putting The Pieces Together

Here are the steps to follow to put your system together:

(1) To set up your Apple II, follow the instructions in the Apple II BASIC Programming Manual. You may not need to attach the Game Controllers, although there is no harm in doing so. Your Apple II must have at least the minimum amount of memory listed under the equipment description for you to use the programs.

(2) If you already have a Disk Operating System, and are using a version of DOS that runs in 13 sectors (DOS 3.2.1 or earlier), you will need to change two proms on your disk controller card to update your system to 16 sectors. Any version of DOS earlier than release 3.3 will need to be updated. These proms are also the same proms that come with the Pascal Language System. Consult a DOS 3.3 manual for these procedures.

References

1. Jenrich, Robert I., "Stepwise Regression", Mathematical Methods For Digital Computers, Edited by A. Ralston and H.S. Wilf, Wiley, 1977.

2. Snedecor, G.W., and Cochran, W.G., Statistical Methods, 6th Edition, Iowa State University Press, Ames, 1967.

STEPWISE MULTIPLE REGRESSION

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